Space Network Loading

CY 2003 - 2010

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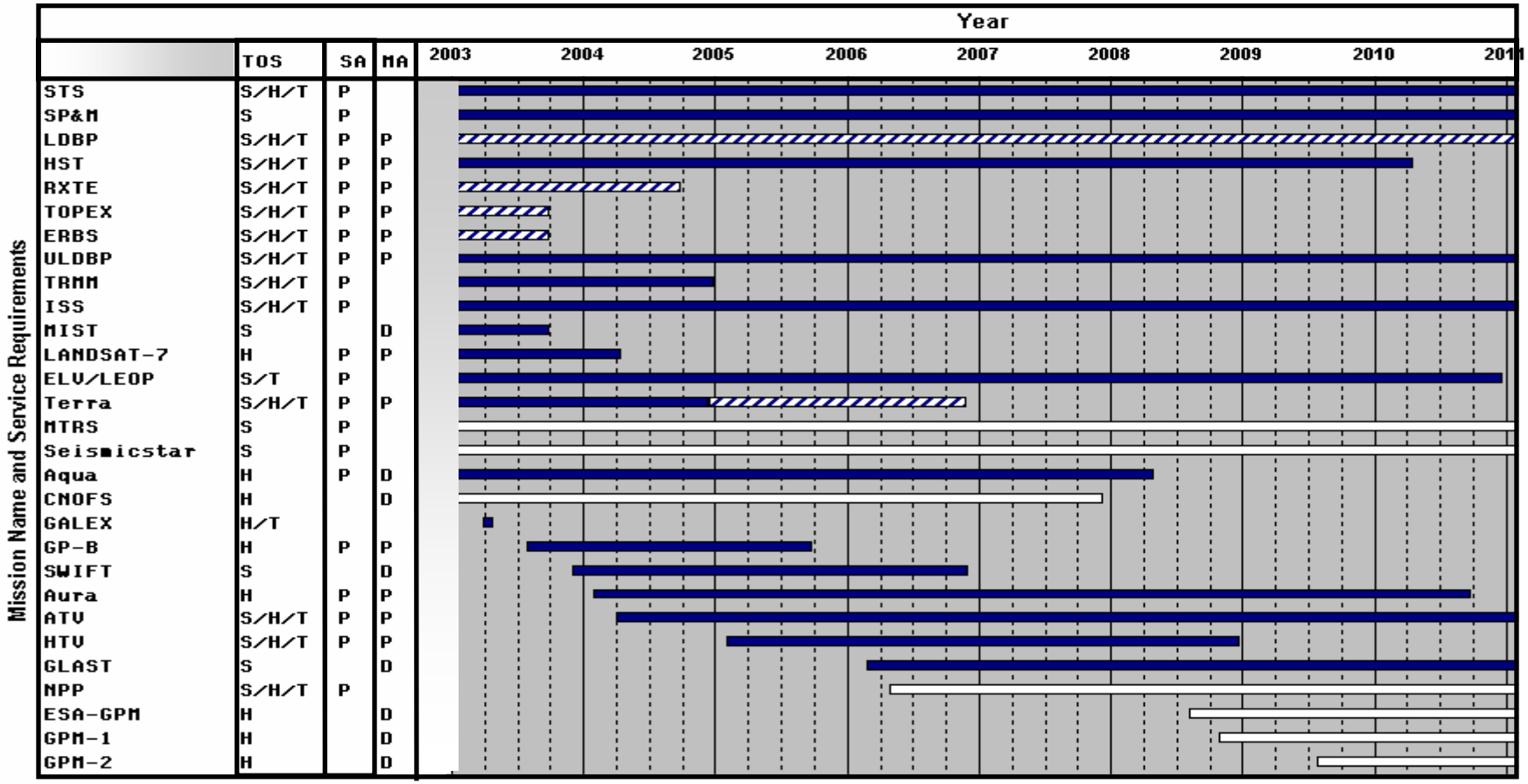
AGENDA

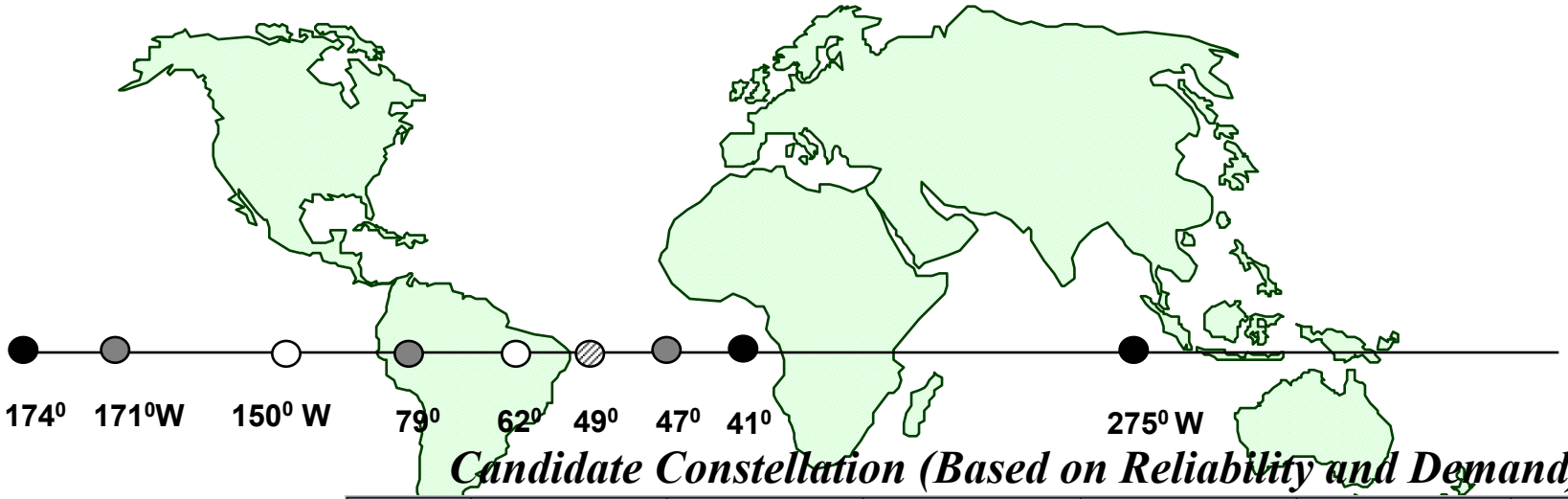
- SN Summary Overview
  - Mission and Resource Model
  - Modeling Assumptions and Approach
  - Peak Loading Considerations
  - Network Utilization and Loading Analysis Results
  - Conclusions and Recommendations
- SN Detailed Analysis
  - TDRSS Reliability Model
  - Projected SA Service by TDRS
  - Loading Analysis Results
    - SA/MA/SMA/DAS

SN Mission Model (2003 to 2011)



Note: ATV support runs for 6 months and off for 12 months

Future Constellation Architecture 2003-2011



Candidate Constellation (Based on Reliability and Demand)

Constellation Goal

- 1st Generation TDRS
- 2nd Generation TDRS
- Open Slot
- NASA/NSF asset

Timeframe Modeled	41 Degrees West Long.		47 degrees West Long.		171 Degrees West Long.		174 Degrees West Long.		275 Degrees West Long.		Total No. of SA's
1Q03 - 1Q04	2	(F4)	2	(F6)	2	(F8)	2	(F5)	2	(F3)	10
2Q04 - 2Q06	2	(F4)	2	(F6)	2	(F8)	2	(F5)	2	(F7)	10
3Q06 - 2Q09	2	(F9)	2	(F6)	2	(F8)	2	(F5)	2	(F7)	10
3Q09 - 4Q10	2	(F9)	2	(F6)	2	(F8)	2	(F10)	2	(F7)	10

Modeling Assumptions and Approach

- Analyze routine, peak, and customer or Network defined critical loading situations
- Modeling tools use geometric calculations and simulated scheduling methods to quantify network loading
- Spacecraft attitude/antenna pointing limitations accounted for when available
  - full coverage assumed for ISS to cover all attitude and blockage possibilities
- Candidate TDRSS constellations evaluated using both reliability/replenishment and demand models

Modeling Assumptions and Approach (Cont.)

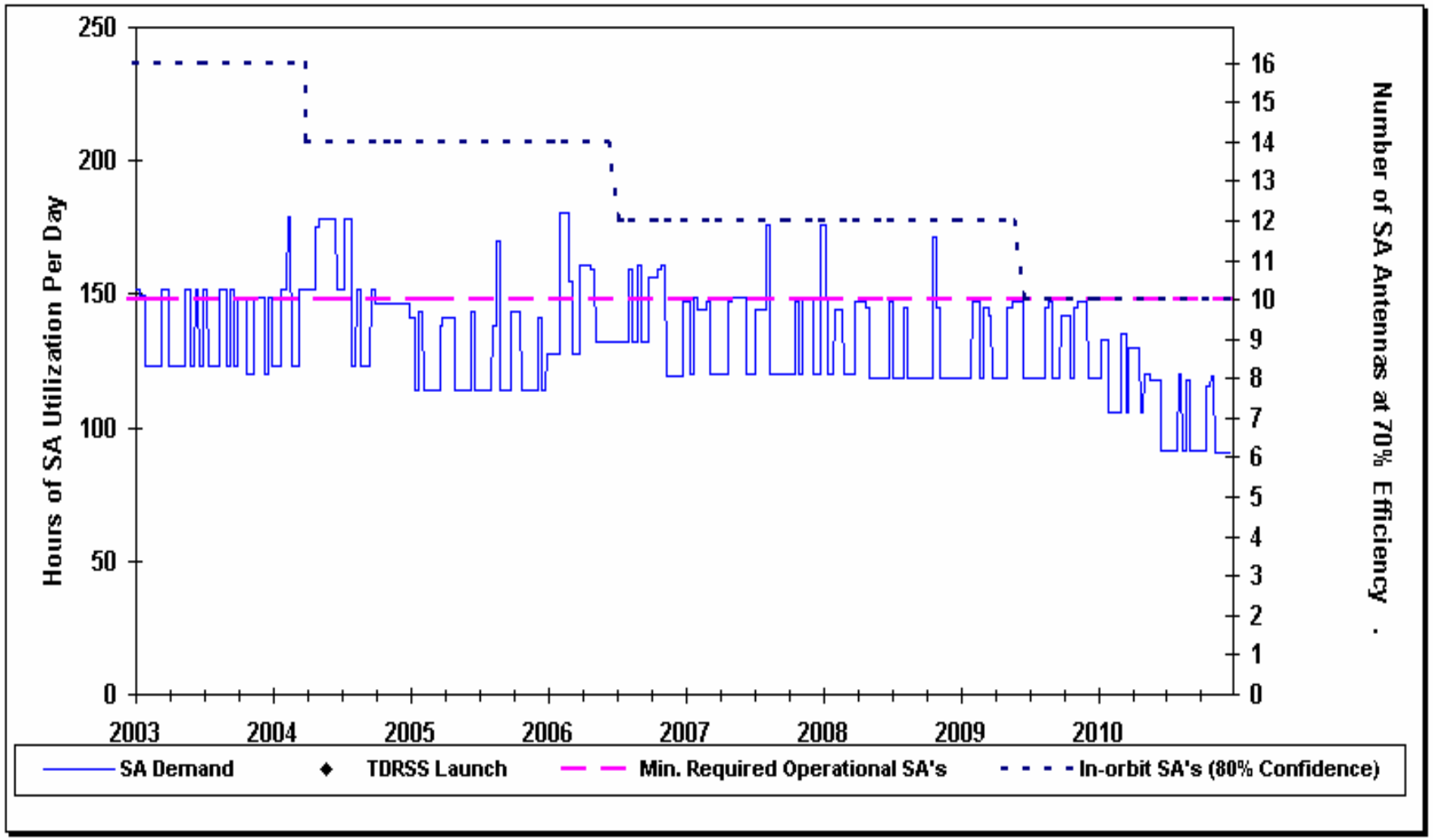
- Principal driver, from a reliability standpoint, for TDRSS constellation definition is the SA service
- TDRS-I/J enhanced MA (SMA) capabilities modeled
  - Return data rates up to 3 MBPS (S-band)
  - One forward link per relay satellite (at 43.6 dBw EIRP)
  - SMA performance on TDRS-8 is currently at first generation MA level
- Demand Access System (DAS) analysis included
  - Target start date October 2003
  - Starting Mid 2009 there is no DAS in the Western Node

Peak Loading Considerations

- STS mission: “frequent flyer”
- Numerous high priority short duration support requirements
  - ELV launches (from 1.5 to 17 hours continuous support SSA including launch delay window)
    - GALEX dual link modeled as primary peak load element
  - LEOP support (for example, GP-B, GALEX)
  - HST servicing missions (requiring for specific periods one SA antenna each for HST and the Space Shuttle)
- Occasional Target of Opportunity Science requirements
  - Natural and cosmic events

Priority will be necessarily high

SA Demand Versus TDRSS On-Orbit Capacity



Note: Minimum required operational SA's reflects 4 SA's in East Node, 4 SA's in West Node, 2 SA's in ZOE to meet the projected demand while providing needed operational balance.

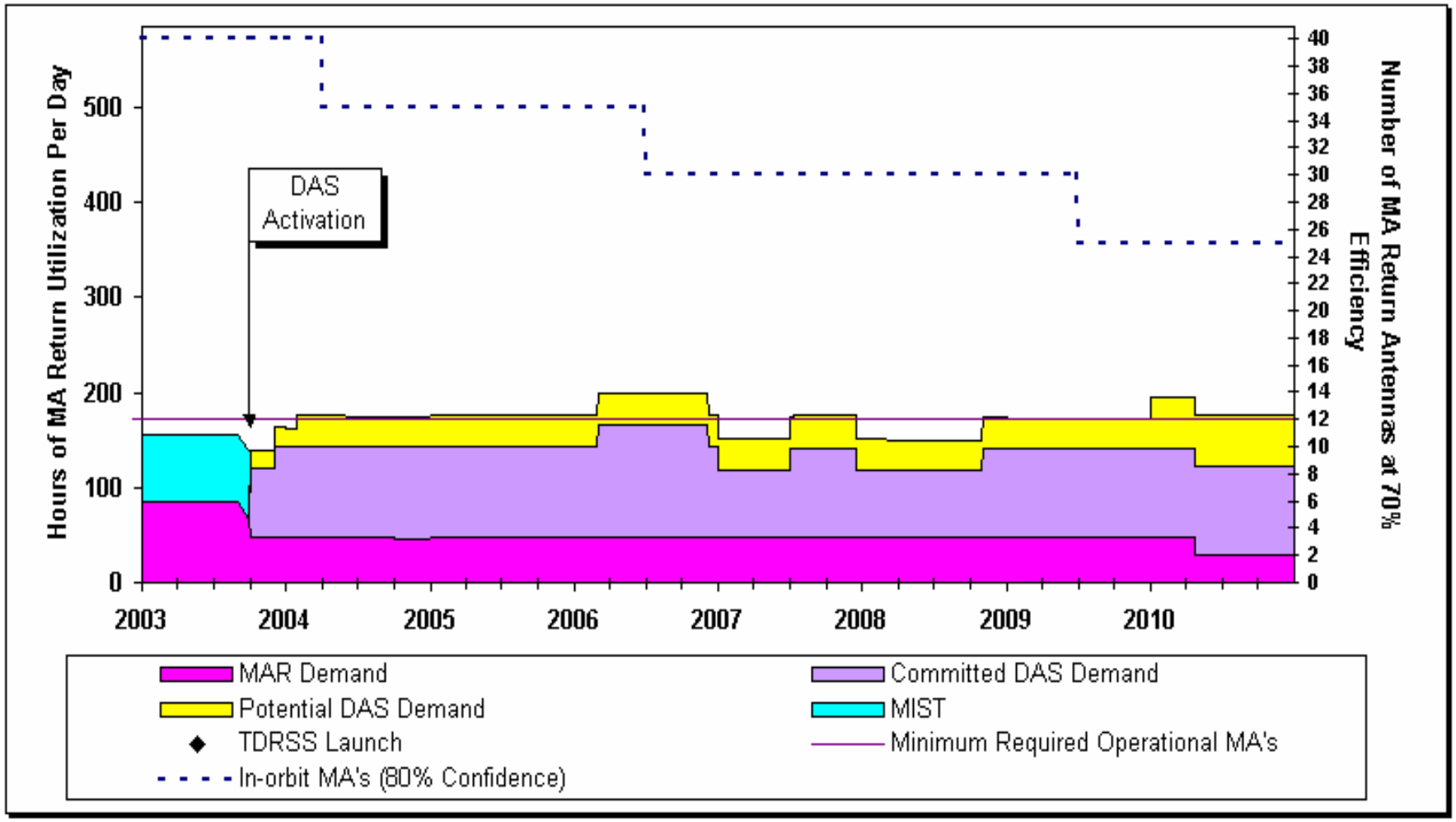
SA Results

- Loading without Shuttle
  - All users (except HST 84%) receive over 90% of the customer service satisfaction for the period 2003 to 2011
  - Maximum loading is 56%
- Loading with Shuttle
  - All users (except HST 73%) receive over 90% of the customer service satisfaction for the period 2003 to 2011
    - HST will be increasing science requirements after Servicing Mission 4
  - Maximum loading is 67%

SA Results (Cont.)

- Peak Loading
  - All users (except HST 52%) receive at least 83% of the customer service satisfaction for the period 2003 to 2011
  - Core Human Space flight elements receive above 90% service satisfaction
  - Maximum loading is 74%

MA Demand Versus TDRSS On-Orbit Capacity



Note: Minimum required operational MA's reflects 5 MAR's (1 TDRS) in East Node, 5 MAR's (1 TDRS) in West Node, 2 MAR's (1 TDRS) in ZOE to meet the projected demand while providing needed operational balance.

MA Results

- All MA users forecasted to receive at least 99% of their telecommunications requirements
- Return Loading utilization peaks at 16% in 2003
- Forward Loading utilization peaks at 18% in 2003
- “911” service supplied to Aqua until DAS is available.
  - 4% increased load on MAR during this timeframe

SMA Results

- TDRS-I/J SMA, pending successful completion of testing, could help relieve SA contentions
  - TOPEX, XTE, Landsat-7, GP-B, and the EOS missions (except Terra) SSA service requirements can be accommodated by SMA on TDRS-I/J
  - Up to 10 hours per day of off-loading possible starting in FY 2003

DAS MA Results

- All Demand Access Service (DAS) MA users forecasted to receive their telecommunications requirements until mid 2009 when DAS is no longer able to provide global coverage
- Return Loading utilization peaks at 52% in 2009 and 2010
- DAS currently scheduled to be implemented October 2003
- DAS customers
  - Committed: SWIFT, GLAST, LDBP, ULDBP,CNOFS, GPM-1
  - Potential: AQUA, AURA, GPM-2, ESA-GPM
- MIST uses DAS concept with their own beamformers. Reported as system usage

DAS MA Results (Cont.)

- If DAS not implemented, MA Return loading peaks at 37% (of 22 operational return channels) in 2009 and 2010
  - Equates to 69% of the minimum 12 operational MAR
- Starting mid 2009, there is no DAS in the Western Node
  - Propose to colocate F5 in the Western Node and reassign SGLT's
  - Propose to update SGLT 3 to have MA capability

Conclusions and Recommendations

- Sufficient resources exist with TDRS-8/I/J to service committed missions through CY 2010
  - 80% TDRSS reliability confidence level
  - One issue is with critical operations
    - For ISS rendezvous operations, multiple SA antennas required simultaneously in each hemisphere
      - Generic loading may be moderate, but conflicts will still result if other missions are relatively inflexible or demanding
    - Other programs may have similar needs as the ISS (for example, ELV range safety, targets of opportunity due to cosmic events or disaster support)
    - Advance negotiations and adherence to agreements will be necessary to satisfy all concerned customers. Compromise is strongly encouraged
    - Missions must have more flexibility in scheduling or accept greater losses

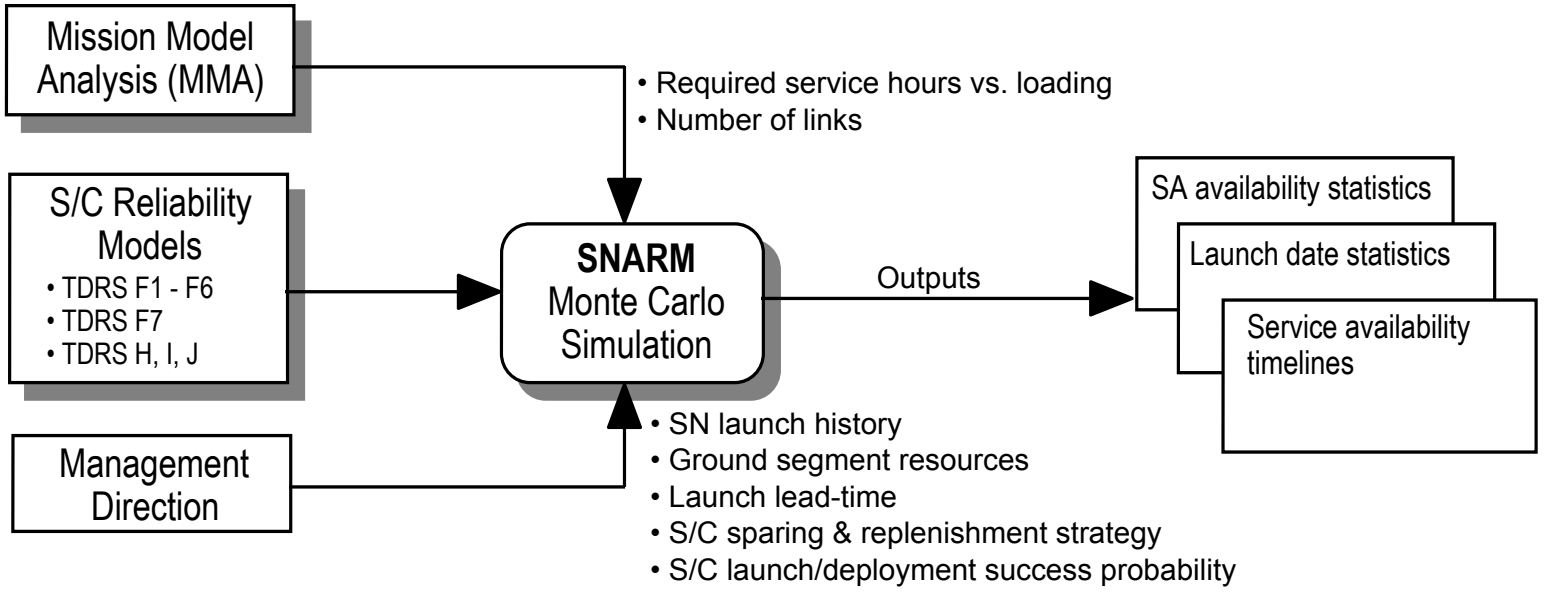
Conclusions and Recommendations (Cont.)

- Sufficient resources exist with TDRS-8/I/J to service committed missions through CY 2010
  - Second issue is DAS reduction in mid 2009.
    - A solution is colocate remaining 1st generation TDRS with MA capability and reassign SGLT's and / or update SGLT 3
- ISS operations requirements will need to be reevaluated as the program grows
  - Commitment is for one full time SA service (includes SSA & KSA)
  - Except for critical support, current policy is for additional SA service to be supported at priority below other programs
- Third generation TDRS should not be required until end of 2012

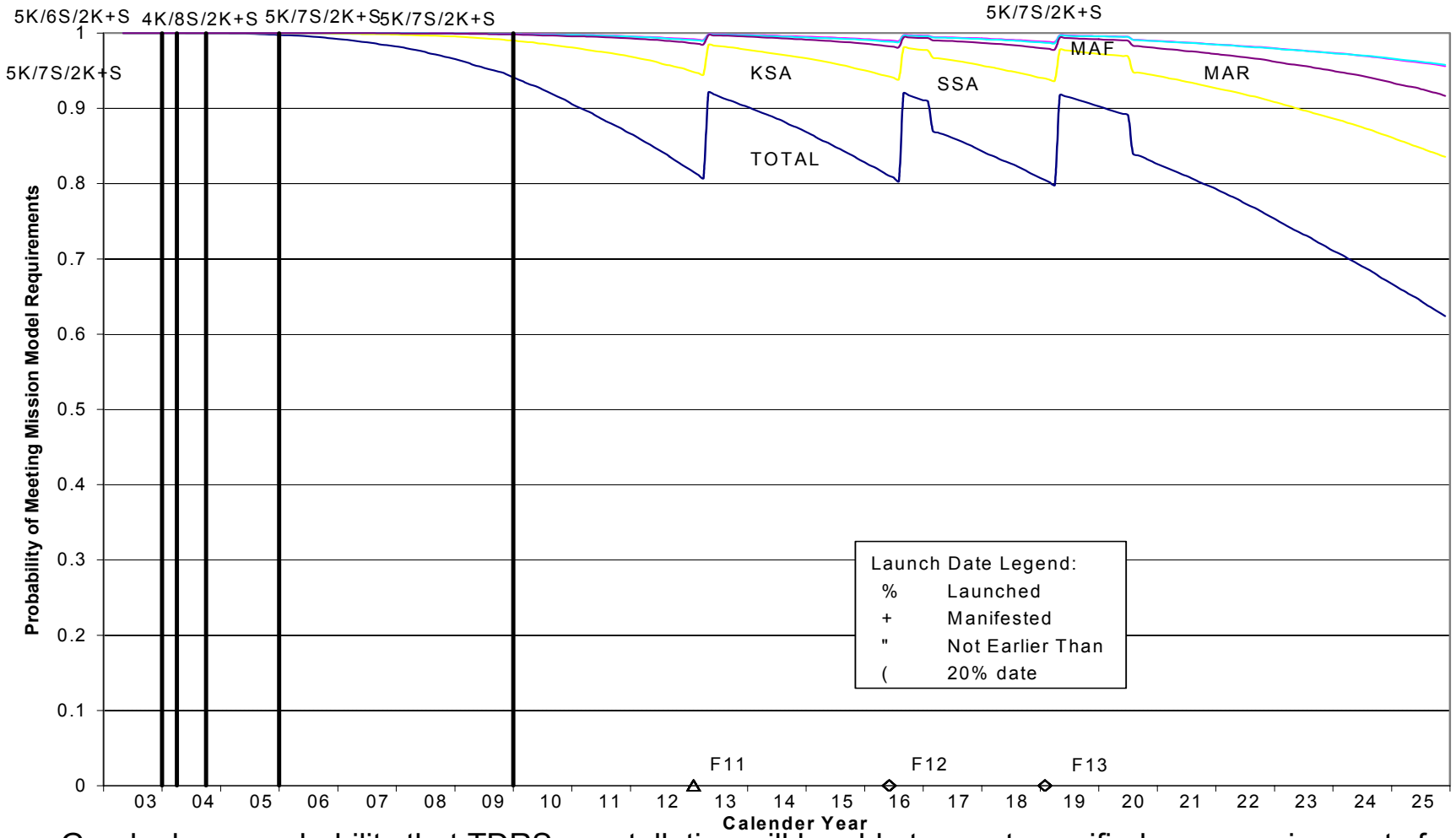
Space Network Detailed Analysis

TDRSS Reliability Model

- The TDRSS spacecraft reliability model has been used since 1985 for SN replenishment planning and service availability analysis
  - → Mission Model Analysis (MMA) tool provides quick-look to quantify the number of SA and MA services required for various levels of network loading
  - → The spacecraft reliability model is an analytical model based on the MIL-HDBK-217 "piece-part" technique in which expressions for spacecraft subsystem reliability are derived
  - → SNARM (Space Network Availability and Replenishment Model) simulates the failure and replenishment of TDRSS spacecraft using Monte Carlo methods
- The interaction of these tools is illustrated below:



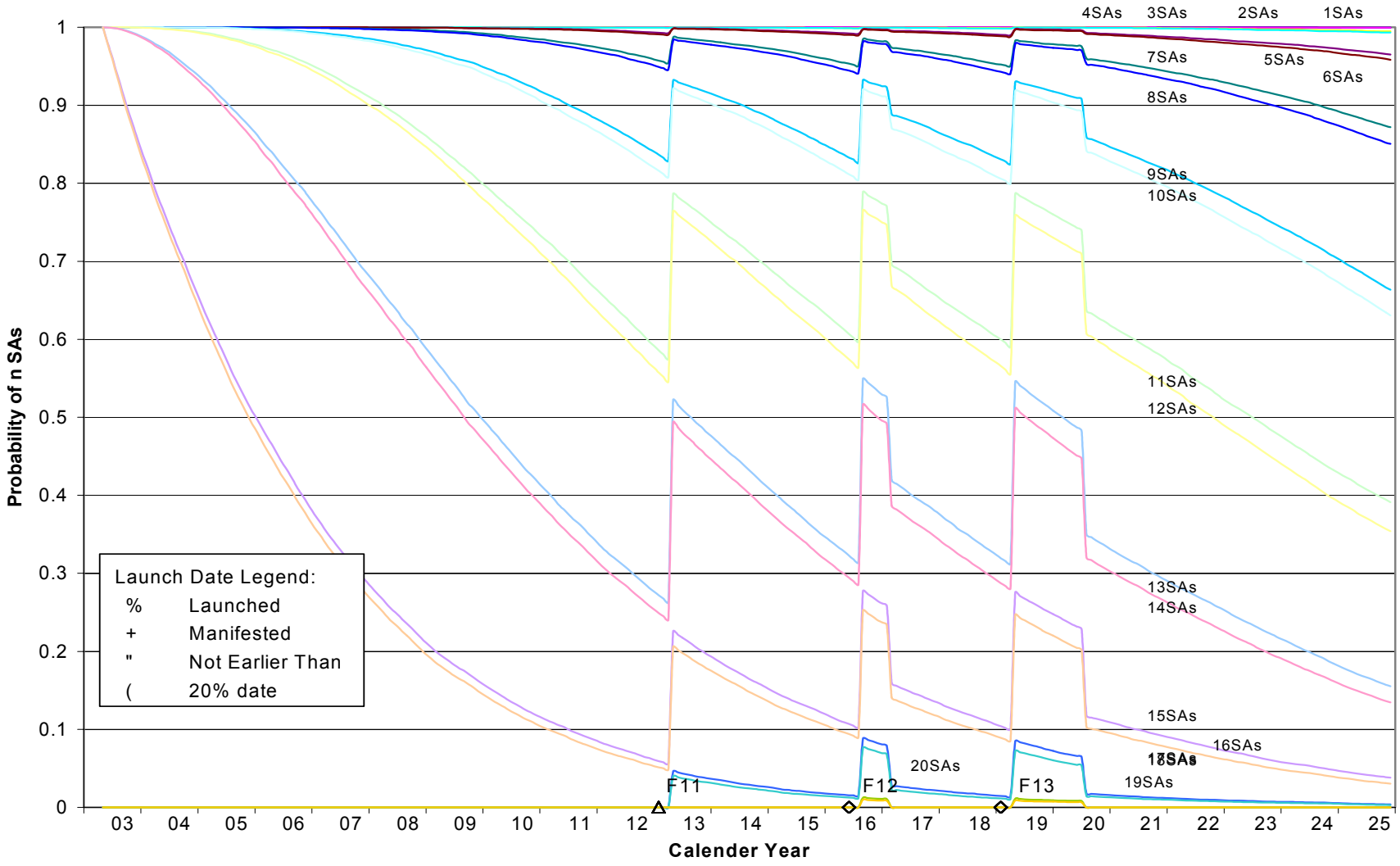
TDRSS Reliability Model (Cont.)



Graph shows probability that TDRS constellation will be able to meet specified user requirements for each type of service.

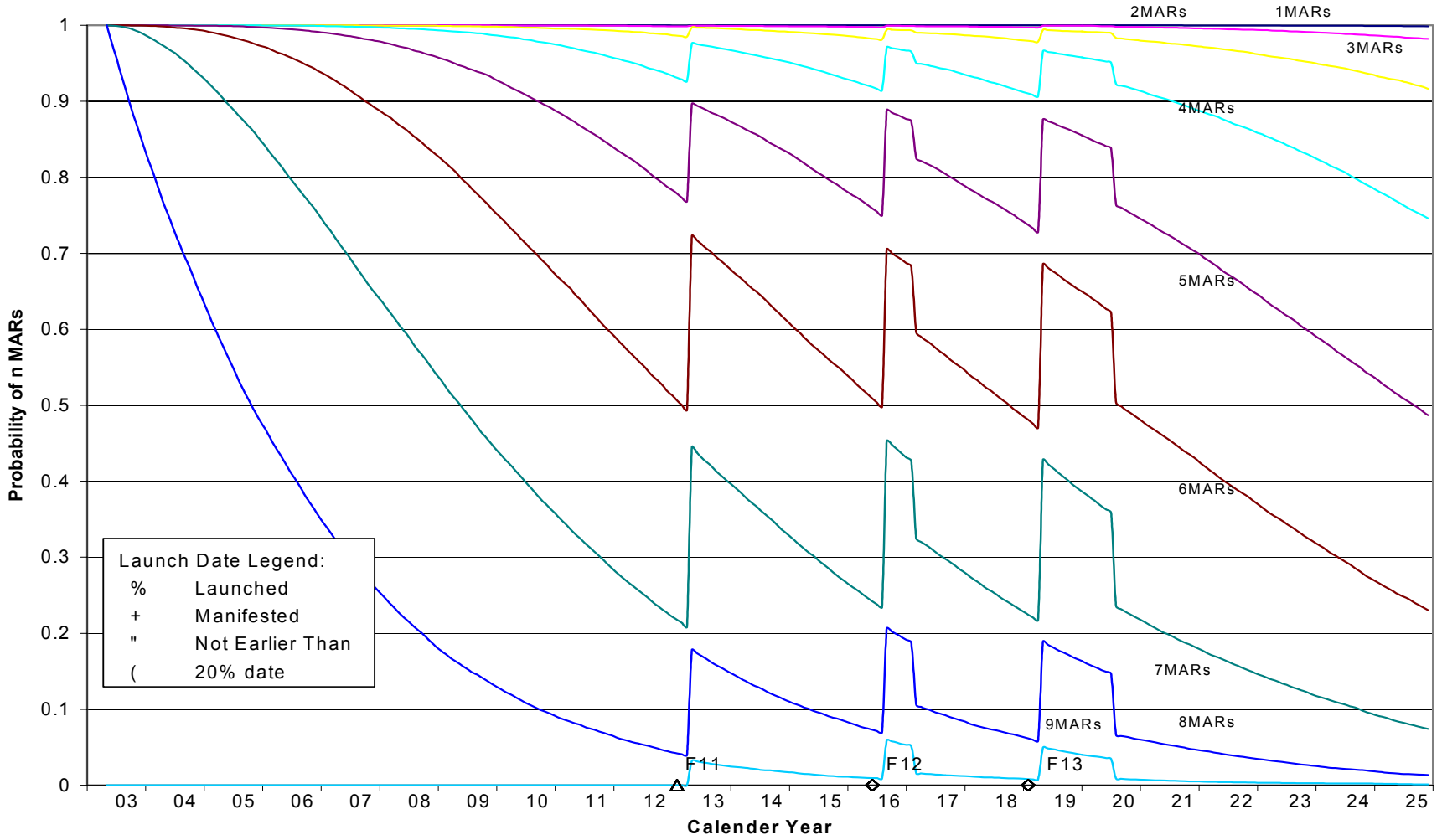
TDRSS Reliability Model (Cont.)

Single Access Services



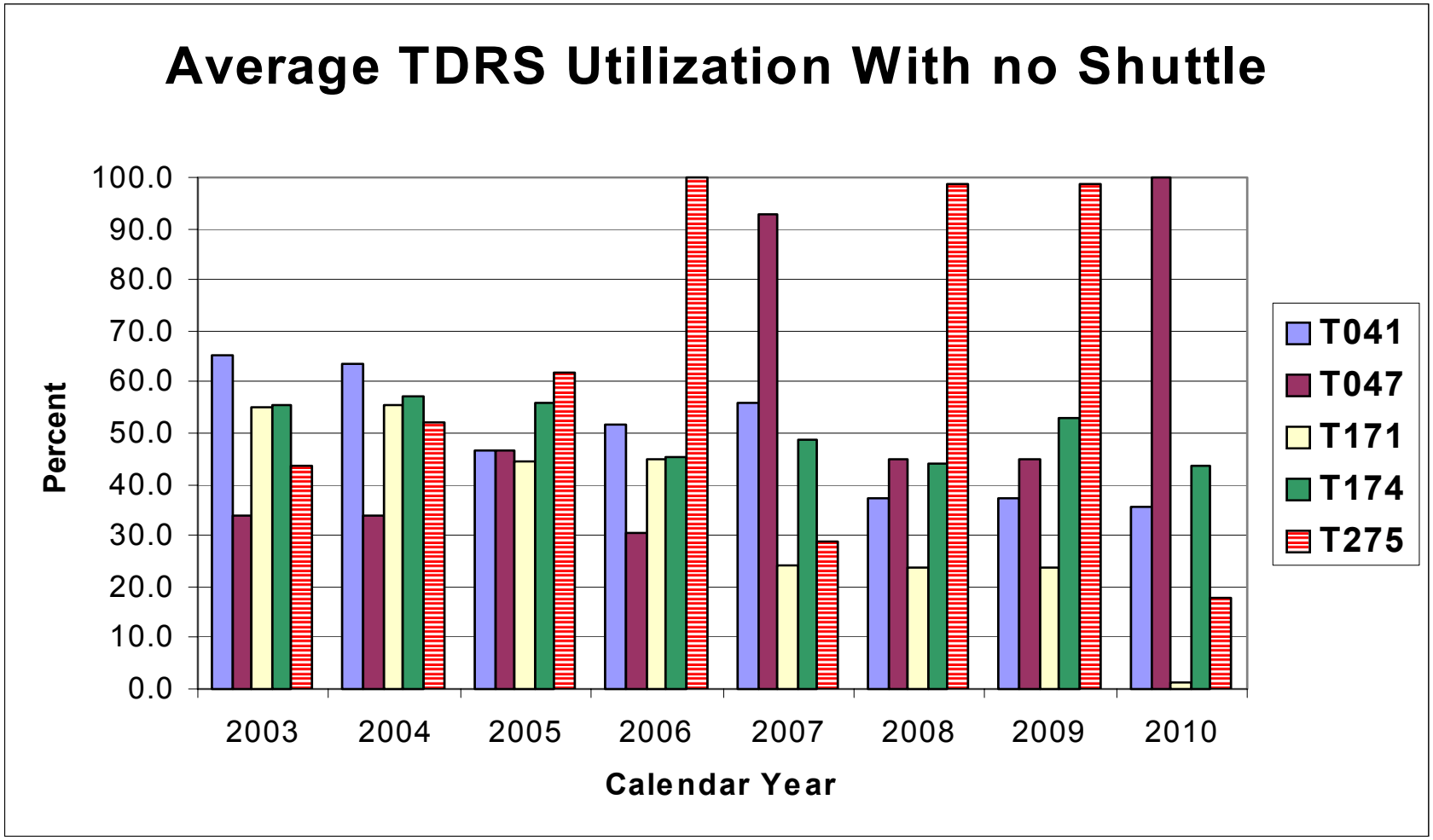
TDRSS Reliability Model (Cont.)

Multiple Access Return Services

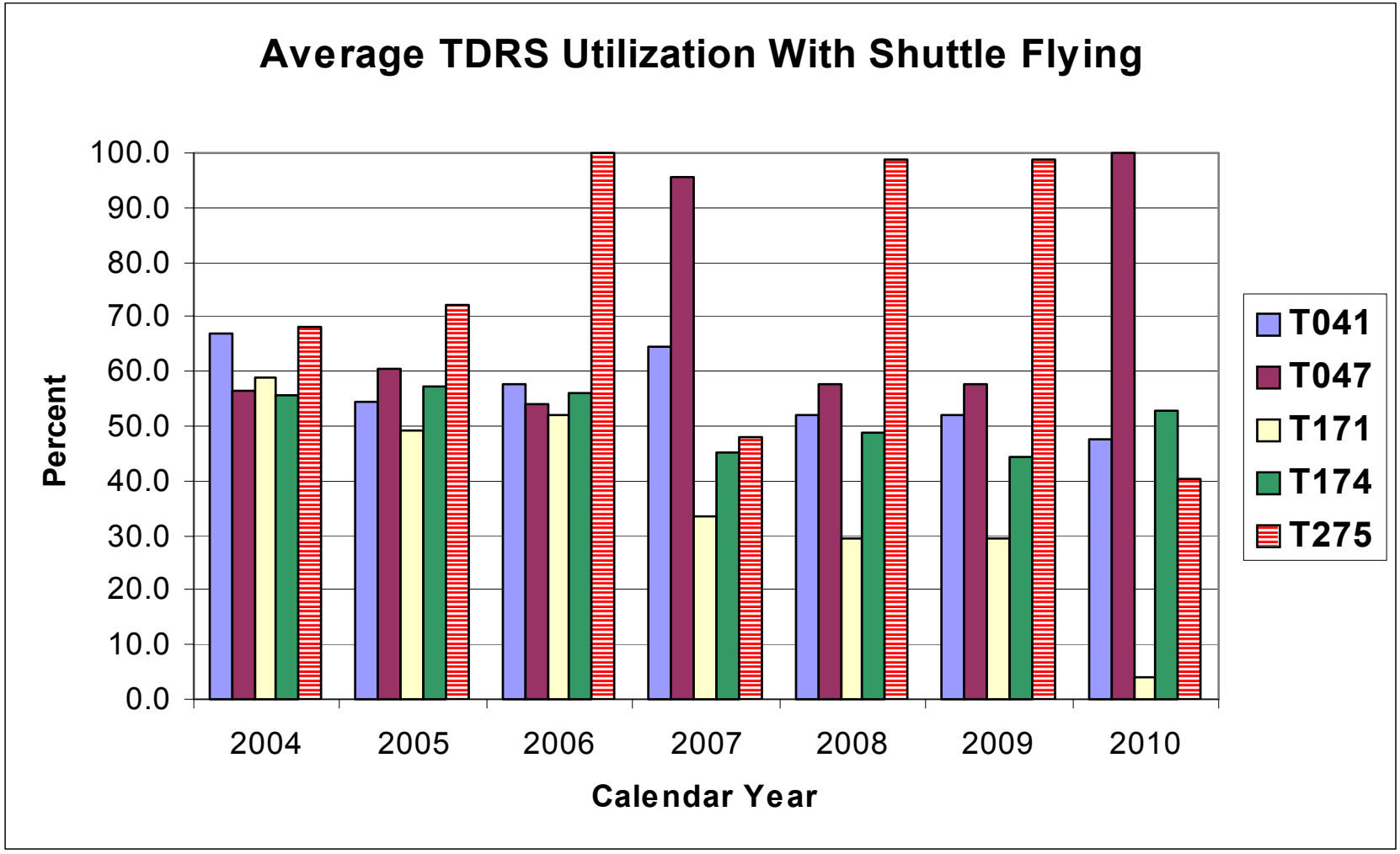


Note: MAR is equivalent to a multiple access capable TDRS

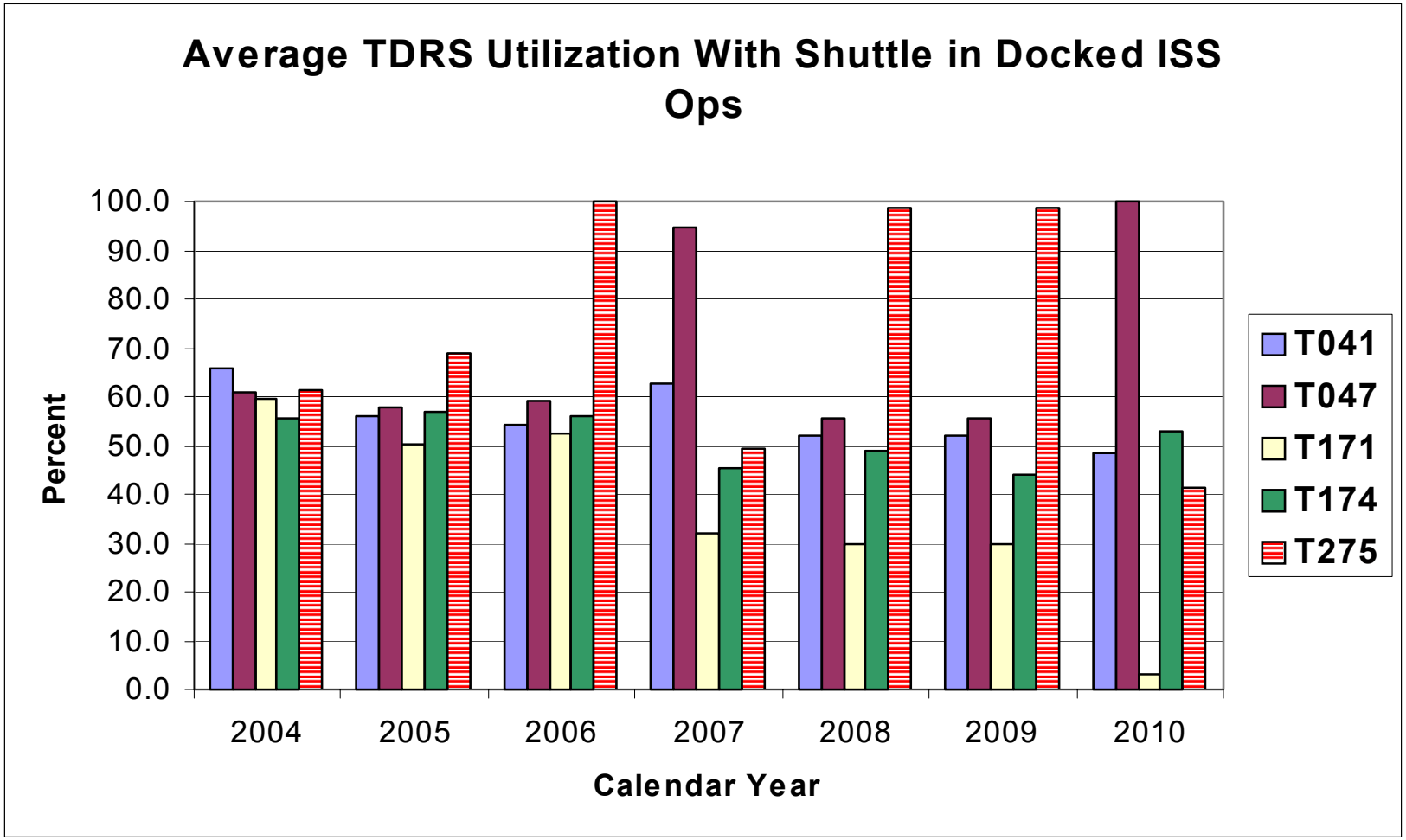
Projected SA Service By TDRS



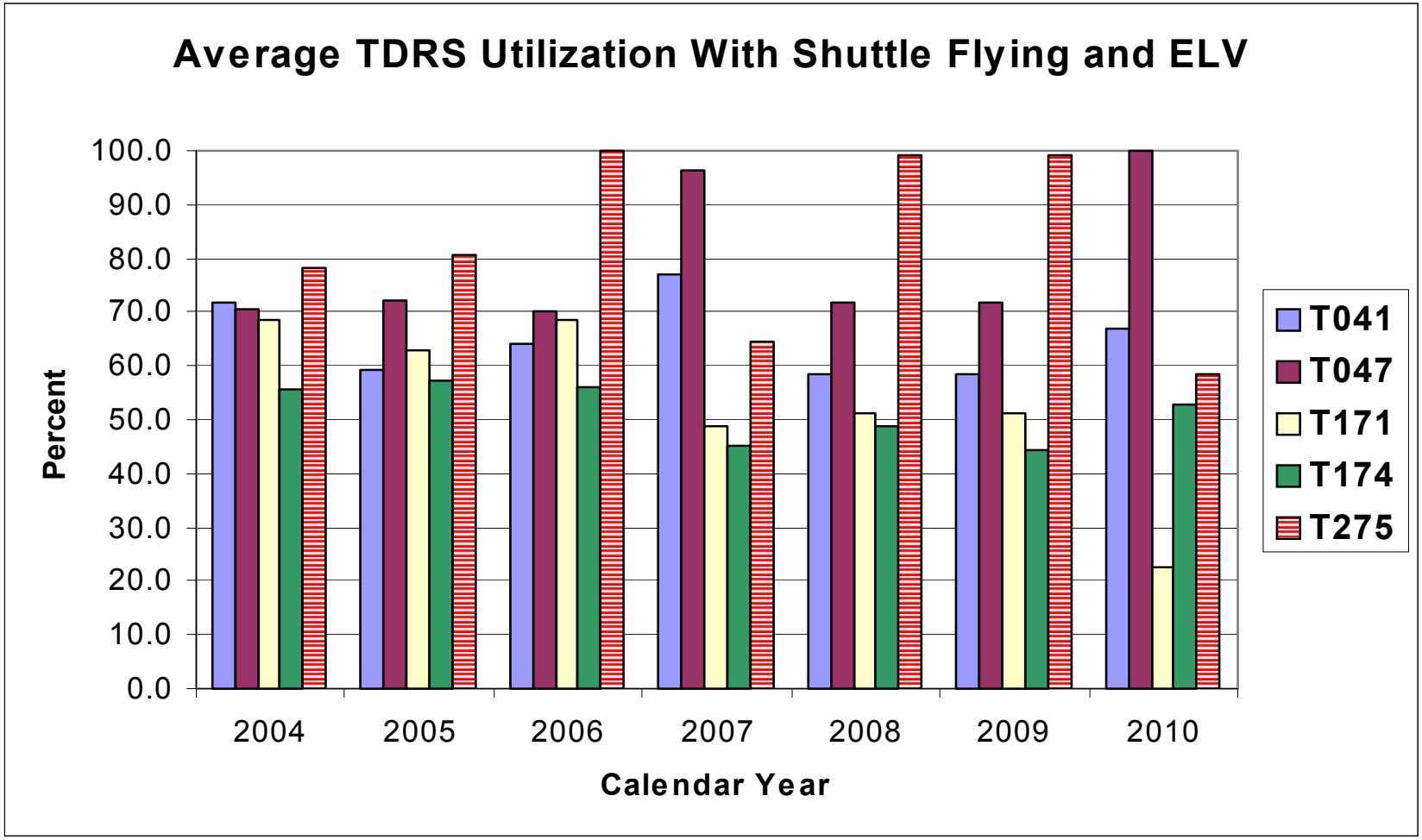
Projected SA Service By TDRS



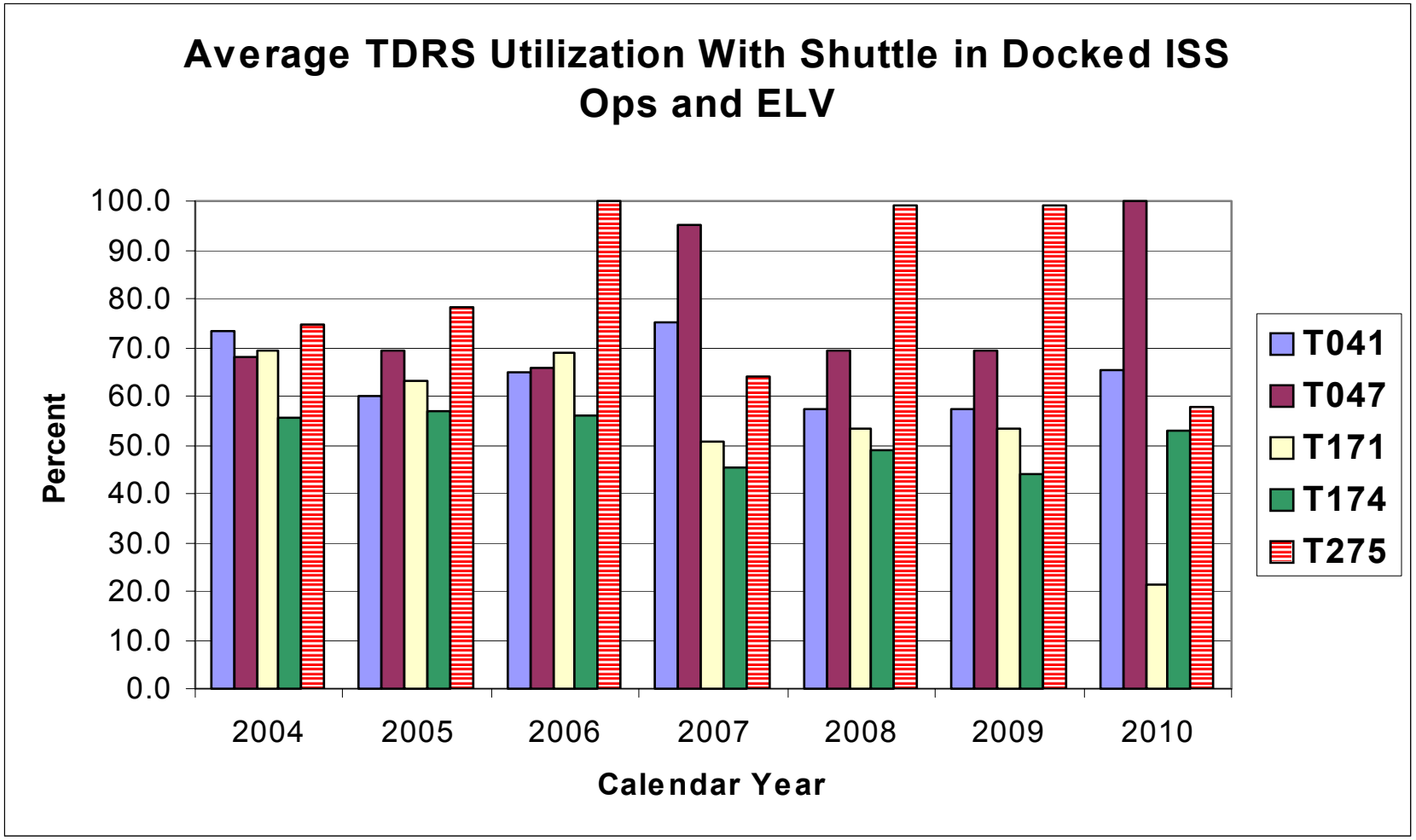
Projected SA Service By TDRS



Projected SA Service By TDRS



Projected SA Service By TDRS



Backup Material

SN Mission Set Orbital Elements

Mission Name	Semi-Major Axis (km)	Eccen.	Incl. (deg)	Rt. Asc. A. Node (deg)	Arg. Of Perigee (deg)	Mean Anomaly (deg)	Apogee Hgt (km)	Perigee Hgt (km)	Incl (deg)	Nodal (sec)	Period (min)
AQUA	7078.050	0.00116000	98.2000	111.1950	90.0000	165.4000	708.125	691.703	98.200	5933	98.88
AURA	7078.050	0.00116000	98.2000	114.9450	90.0000	226.6000	708.125	691.703	98.200	5933	98.88
CNOFS	6933.000	0.02235600	13.0000	0.0000	0.0000	0.0000	709.858	399.870	13.000	5724	95.40
ELV/LEOP	7068.136	0.00010000	29.0000	243.0416	90.0000	0.0000	690.707	689.293	29.000	5895	98.25
ERBS	6961.242	0.00124610	57.0001	61.6723	94.4256	307.5734	591.780	574.431	57.000	5779	96.32
ESA-GPM	6778.136	0.00100000	70.0000	0.0000	0.0000	0.0000	406.778	393.222	70.000	5558	92.63
GLAST	6928.140	0.00010000	28.5000	0.0000	0.0000	0.0000	550.697	549.311	28.500	5722	95.37
GP-B	6978.140	0.00010000	90.0000	0.0000	0.0000	0.0000	600.702	599.306	90.000	5809	96.82
GPM-C	6778.136	0.00100000	70.0000	0.0000	0.0000	0.0000	406.778	393.222	70.000	5558	92.63
GPM-P	6778.136	0.00100000	70.0000	0.0000	0.0000	0.0000	406.778	393.222	70.000	5558	92.63
HST	6976.410	0.00080710	28.4626	77.7614	284.1538	16.3178	603.905	592.643	28.463	5783	96.38
ISS	6822.140	0.00001000	51.6000	0.0000	0.0000	0.0000	444.072	443.936	51.600	5603	93.38
Landsat-7	7078.050	0.00116000	98.2000	238.6950	90.0000	80.2500	708.125	691.703	98.200	5933	98.88
NPP	7211.140	0.00001000	98.7500	301.2500	0.0000	0.0000	833.076	832.932	98.750	6101	101.68
STS	6678.140	0.00010000	28.5000	280.0510	0.0001	0.0001	300.672	299.336	28.500	5414	90.23
SWIFT	6978.137	0.00000000	19.0000	0.0000	0.0000	0.0000	600.001	600.001	19.000	5781	96.35
Terra	7078.050	0.00116000	98.2000	243.7000	90.0000	7.3570	708.125	691.703	98.200	5933	98.88
TOPEX	7709.770	0.00086599	66.0358	256.4274	128.4282	166.4917	1338.311	1324.958	66.036	6740	112.33
TRMM	6728.140	0.00010000	35.0000	0.0000	0.0000	0.0000	350.677	349.331	35.000	5479	91.32
XTE	6958.140	0.00010000	23.0000	90.0000	0.0001	120.0000	580.700	579.308	23.000	5757	95.95

SN Mission Requirements

- **AQUA**: Six 20 minute SSA return / forward events per day. MA may be used as backup for the SSA events. SMA can be used to backup SSA when it becomes available. The spacecraft antenna is masked. When the Direct Access System (DAS) is available schedule 100% DAS MA return. Before DAS becomes available use 100% MA return as "pseudo DAS". Aqua cannot use the TDRS located at 275 degrees West Longitude.

- **AURA**: Five 10 minute SSA forward / return events per day. MA may be used as backup for the SSA events. SMA can be used to backup SSA when it becomes available. The spacecraft antenna is masked. Also schedule 100% DAS MA return.

- **BRTS**: Two pairs of 4 minute collocated events per day. One pair of collocated events is on T041 and one pair is on T174. There are two additional non-collocated pairs of 4 minute events per TDRS every four hours. This comes to six pairs (or twelve total) events per TDRS per day. T041 and T174 have one additional pair of collocated (or two total) events per day. The collocated pairs of events are one MA forward / return event plus one SSA forward / return event. The non-collocated events should end up being nine MA forward / return plus three SSA forward / return events per day per TDRS. There is BRTS on all TDRSs. When SMA becomes available, the MA BRTS will be on the SMA.

SN Mission Requirements (Continued)

- **CNOFS**: Schedule 100% DAS MA return.
- **ELV/LEOP**: (GALEX-like launch simulated) The ELV/LEOP is launched by being dropped from a Pegasus. Two launch opportunities are emulated. There will be launches regularly during the entire span of various "peak" simulations. The ELV/LEOP launch support requirement is for a 3-hour launch window at which time continuous support is required from both TDRS's at 47 and 171 degrees West Longitude. ELV/LEOP requires 14 hours of continuous support following spacecraft separation. The stations which support ELV/LEOP are the TDRS's at 47, 171, and 275 degrees West Longitude. Specific times of overlapping scheduling during the first 5 hours and 16 minutes of support are taken from the GALEX DMR dated January 2002. The overlapping times make the amount of time requested during this period become 9 hours and 5 minutes of SSA support. For the rest of the 14 hours continuous SSA support from one of the stated 3 stations with no overlap was requested. In cases where a TDRS was not available, another TDRS closeby was selected for support.

SN Mission Requirements (Continued)

- **ERBS**: Fourteen 15- to 30 minute MA forward / return events per day. There is a thirty minute separation between services. Schedule events four minutes after the spacecraft enters sunlight and stop the events four minutes before the spacecraft enters darkness. SSA may be used as backup for the MA events. The spacecraft antenna is masked.
- **GLAST**: Schedule 100% DAS MA return.
- **Gravity Probe-B** (GP-B): (On-orbit support) Two 20 minute SSA forward / return events per week. SMA can be used to backup SSA when it becomes available.

SN Mission Requirements (Continued)

- **HST**: Obstruction of S/C antenna is used. HST cannot point within 9 degrees of the earth for MA and 15 degrees for SSA. HST can hold four TDRS ephemerides, but can only use two at a time. HST only schedules on the TDRS's located at 41, 171, and 174 degrees West Longitude. The TDRS at 174 can only use the second SA antenna. HST can't use SMA to replace SSA when SMA becomes available. 100% MA (or SMA) return is scheduled concurrent with following requirements. HST has different requirements depending on the timeframe.
  - HST Post Servicing Mission 3B requirements: 18 approximately 35 minute SSA Forward / Return services per day. Minimum time acceptable can be as low as 15 minutes if required with one additional contingency approximately 35 minute SSA Forward / Return service per day.
  - Fifteen additional 15 - 20 minute SSA Forward / Return services per day.
  - HST Post Servicing Mission 4 requirements: 18 20 minute SSA Forward / 20-50 minute SSA Return services per day with one additional contingency 20 minute SSA Forward / 20 - 50 minute SSA Return service per day.

SN Mission Requirements (Continued)

- **ISS**: (100% In-View Coverage): No obstruction of S/C antenna is used. ISS spacecraft software can use all TDRSs except that due to datarate limitations the TDRS at 275 cannot be used for KSA return.
  - 100% KSA return / SSA forward in-view coverage from T041 and T174. There is 2 minutes handover between services. Fill in with SSA return / forward on T275 to obtain as close to 100% coverage as possible. Do not use SMA to replace SSA when it becomes available.
- **Landsat-7**: Two 10 minute SSA return/forward events per day with MA return /forward as backup. Sixty minute separation between events. Also have two 15 minute MA Return / Forward events per day. SMA can be used to backup both SSA and MA when it becomes available. S-band antenna is masked.
- **LDBP**: Ten minutes of MA forward per hour plus 100 % MA return. SMA can be used to backup MA when it becomes available. No obstruction of S/C antenna is used. When more than one LDPB occur simultaneously, one LDBP will schedule 100% DAS MA return.

SN Mission Requirements (Continued)

- **MIST**: Consists of ground-based transmitters which require DAS-like MA Return service simultaneously from all 3 TDRS nodes. MIST uses the DAS concept, but does not use the DAS equipment, they have their own beamformers co-located at WSGT.
- **NPP**: One 3 minute KuSA return event at 150 MBPS every 1/6 of an orbit (~16.88 minutes) within a window of +/- 2 minutes. Schedule on all TDRS's available except 275 due to datarate limitations.
- **SPTR**: South Pole TDRS Relay (SPTR) schedules daily for four hours per day (2000 to 2400 GMT) on F1 (T049) only. SPTR requires KSAR / SSAR / SSAF. The minimum contact time is five minutes and maximum contact time is four hours.

SN Mission Requirements (Continued)

- **STS**: Use obstruction of STS K-Band antenna; no obstruction of the S-Band antenna is used. Do not use SMA for SSA when it becomes available.
  - Operations Data Recorder dump of one 2 minute KSA return event every half orbit.
  - Additionally, 100% SSA return / forward in-view coverage is requested. The minimum contact time is two minutes. The maximum contact time is as long as possible. In order to allow for lower priority missions to have time to schedule, the STS request was modified to have 95% of the STS SSA return / forward requirement requested at a high priority and fill for any other SSA return / forward support at a lower priority.
- **SWIFT**: Schedule 100% DAS MA Return.

SN Mission Requirements (Continued)

- **TERRA**: One 25 minute KSA return event plus one 15 to 25 minute long SSA forward / return event per orbit. The KSA must schedule before the SSA, and they can't be scheduled simultaneously. The two events may schedule "back to back" if necessary. When the EPGN can support X-band for Terra starting in 2001, these SN passes cannot occur simultaneously with X-band events. Sometimes the SSA event is reconfigured to become a KSA event if the KSA has to be cancelled. The spacecraft antenna is masked.

- **TOPEX**: Requirements are based on actual loading during the January – February 2003 timeframe. One critical 30 - 55 minute MA Forward / Return event every 8 hours. Non-simultaneous with the critical events, schedule 12 10 - 15 minute SSA Return / Forward events per day. Also schedule four 30 - 45 minute MA Forward / Return events per day plus 8 additional 1 - 35 minute MA Forward / Return events per day. SMA can be used to backup SSA and MA when it becomes available. The spacecraft antenna is masked.

SN Mission Requirements (Continued)

- **TRMM**: One 14 to 20 minute SSA forward / return event per orbit. Do not use SMA for SSA when it becomes available. The spacecraft antenna is masked.
- **UARS**: Two 15 minute SSA forward / return events per day. Twenty-six 15 to 18 minute MA forward / return events per day. Schedule a minimum of 70% of each event when the spacecraft is in sun. The spacecraft antenna is masked. Do not use SMA. Limited to any three first-generation TDRS's.
- **ULDBP**: Schedule 100% DAS MA Return.
- **ISS VISITING VEHICLE**: The Visiting Vehicle to ISS emulates either ATV or HTV. 100% SSA return / forward in-view coverage from TDRSs in different nodes. Choose support from T041 and T174 if possible, if not pick TDRSs in different nodes. Do not use SMA for SSA when it becomes available. The TDRS at 275 can be used for Visiting Vehicle support. No obstruction of S/C antenna is used.

SN Mission Requirements (Continued)

- **XTE**: One 12 to 20 minute SSA forward / return event every other orbit. One 15 minute MA forward event on the orbits SSA is not supposed to be scheduled. 100% in-view MA return non-simultaneous with the SSA. SMA can be used to backup SSA when it becomes available. No obstruction of S/C antenna is used.

- **SeismicStar**: (commercial venture) not included
  - KSA service scheduled within 48 hours of service start
    - Uses TDRSS Unscheduled Time (TUT)
    - Nonimpacting to NASA missions
  - Service is "best available"
    - Program goal is 3000 minutes/day (50 hours)
      - Equates to ~21% additional loading on SA